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Engineering Properties of Peeled and Unpeeled Multiplier Onion

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Abstract

Multiplier onion (*Allium cepa* L. var *aggregatum*. Don.) is mainly used for its unique flavour in seasoning dishes. The unpeeled onions are processed at farm level by means of primary processing and by secondary processing various products like paste, flakes, powder could be produced from peeled onions. For the design of processing and handling equipment knowledge of engineering properties is essential. The engineering properties of peeled and unpeeled multiplier onion were determined. The average values of the physical properties of unpeeled onion were recorded for bulk density and true density as 636.621 and 1526.825 kg/m^3 respectively. Similarly for peeled onions, the bulk and true density were 627.03 and 1108.74 kg/m^3 respectively. The moisture present in peeled and unpeeled onion was 77.66 % and 74.43% (w.b) respectively. The TSS of multiplier onion was found to be 20° Brix for both peeled and unpeeled samples. The colour values were also measured using colour flex meter for the peeled and unpeeled onions. The frictional properties including coefficient of friction, filling and emptying angle of repose were also measured. Mechanical properties were determined by using a texture analyser. The firmness was measured in terms of penetrating force and crushing strength which were recorded to be 8.59 N and 124.93 N respectively for peeled and 12.00 N and 138.35 N respectively for unpeeled onions.

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Introduction

Aggregatum onion (*Allium cepa* L. var. *aggregatum* Don.) is one of the oldest bulb crops consumed in certain countries across the globe. It is known by various names such as multiplier onion or potato onion and also as underground onion. In countries *viz.,* Thailand, Indonesia, the Philippines, Sri Lanka and India, multiplier onions are cultivated commercially both for domestic and international markets. Multiplier onions contain protein, vitamin

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C, B vitamins, iron, minerals viz. potassium, phosphorus, calcium and zinc[1]. Multiplier onions are known for its pungency. They are used in the Indian kitchen for seasoning of curries and is believed to have medicinal properties. As a folk medicine, it is used to bring down fever and to heal wounds. It is also consumed to reduce the blood sugar level. Primary processing of multiplier onion in unpeeled form involves cleaning, grading, storage etc. Multiplier onion when peeled can be further processed to make different products *viz.,* paste, flakes, powder etc. by means of secondary processing.

When in raw form, a food product possess unique characteristic due to its biological nature. Processing and preservation of food involves several unit operations which alters their properties. Any characteristic that could affect during handling or processing of biological material can be termed as an engineering property. Knowledge of the engineering properties of food material helps in the design of postharvest processing and handling equipment. Engineering properties have been studied for different onion cultivars and other commodities by earlier researchers[2,3,4,5,6,7&8].

Measurement of physical properties *viz.,* shape, size, volume, surface area, density and porosity helps in the design of graders, sorters, handling and storage structures. Study on the chemical properties, which reveals the nutritional compositions and moisture content, is useful for estimating densities and thermal properties. Mechanical properties focus on strength of properties and testing such as compressive strength and deformation. Frictional properties, *viz.,* Coefficient of friction, angle of internal friction and angle of repose are important in designing of storage bins, hoppers, chutes, screw conveyors etc.

The present study will mainly focus on engineering properties of multiplier onion, for both peeled and unpeeled onions and this data will help in the design and development of primary processing and secondary processing equipment for onion.

Materials & Method

Raw material

The multiplier onions used for this study was purchased from a local market in Coimbatore, Tamil Nadu. The multiplier onions were peeled using a stainless steel knife. One set of experiment was conducted for unpeeled onions and another for peeled onions.

Physical Properties of Multiplier Onion

The physical properties of onions such as size, shape, volume, bulk density, true density etc. were measured.

Size & Shape

A vernier calliper having a least count of 0.01 mm was used to measure the major dimensions *viz.,* length, width and thickness of the samples.

The geometric mean diameter was calculated from the equation[9]

$$D_{gm} = (lwt)^{1/3} \quad ...(1)$$

Where,
D_{gm} - geometrical mean diameter, mm
l – length of onions, mm
w – width of onions, mm
t – thickness of onions, mm

The arithmetic mean diameter (D_{am}) is the sum of all the three linear dimensions namely length, width and thickness of the sample divided by the total number of linear dimensions.

$$D_{am} = (l+w+t)/3 \quad ...(2)$$

The shape of a food material is usually expressed in terms of its sphericity, which is determined using the expression below[9]

$$s= (lwt)^{1/3} /l \quad ...(3)$$

For a better understanding of the shape of onion, another shape determinant called aspect ratio was also determined.

$$\text{Aspect Ratio, } A_R = l/w \times 100 \quad ...(4)$$

True Density

This is the ratio of mass of sample to its pure volume. True density was measured by the water displacement method, by dropping fifty numbers of individual onion bulbs into water taken in 100 ml measuring cylinder. The weight of fifty numbers of onion was weighed in an electronic balance prior to

start of the experiment. The rise in water level, which is proportional to the volume of the onion bulbs, was noted. The true density experiment was replicated three times and the average value reported.

Bulk Density

Bulk density was determined by filling and weighing the onion in a container of known volume. The ratio between the mass and volume was calculated as bulk density. The experiment was replicated thrice.

Bulk density = Mass/Volume

Chemical Properties of Multiplier Onion

Moisture Content

Moisture present in peeled and unpeeled onions was estimated using hot air oven method. In one set of experiment, onions were peeled manually by removing the outer skin and chopped. About 10 g of peeled and unpeeled onions were dried in hot air oven at 60°C till a constant weight was obtained10. The observations were recorded and weighed on an electronic balance to a precision of 0.01g and also replicated three times. The moisture content was calculated using the formula,

$M_{wb} = ((W_1-W_2))/W_1 \times 100$

Where,
M_{wb} – Moisture content, per cent wet basis
W_1 – Initial weight of the sample, g
W_2 – Final weight of the sample, g

Total Soluble Solids

Total soluble solids content of a solution is determined by the index of refraction. This is measured using a refractometer and is mentioned as degrees Brix. Known quantity of onion bulbs were crushed by using pestle and mortar. The crushed juice was placed in the hand held refractometer (0-32°; ERMA, Japan) and the readings were recorded. The experiment was repeated three times.

Colour

Colour flex meter (Hunter Associates Laboratory, Inc.) was used for the measurement of colour of the peeled and unpeeled onions. Colour parameters were expressed as L* describing lightness (L*= 0 for black, L* = 100 for white), a* describing intensity in green-red (a* < 0 for green, a* > 0 for red), b* describing intensity in blue – yellow (b* < 0 for blue, b* > 0 for yellow).

Frictional Properties of Multiplier Onion

Angle of Repose

Filling Angle of Repose

Filling angle of repose is the angle between the base and the slope of cone formed on a free vertical fall of the sample to a horizontal plane. Known quantity of onion was piled over a horizontal surface. The radius of the pile was calculated from the circumference of the pile and the slant height of the pile was determined by measuring actual slope of the pile. The experiment was replicated five times and repeated for unpeeled onion also.

$\tan\theta = 2h/d$

Where,
h = height of the pile, cm
d = diameter of the pile, cm

Emptying Angle of Repose

To determine the emptying or dynamic angle of repose, a rectangular box (10 cm width and 15 cm length) with removable front panel was used. The box was filled with the onion bulbs, and then the front panel was quickly removed, allowing the onion bulb to flow and assume a natural slope. The angle of repose was calculated from the measurement of the depth of free surface of the sample at the centre.

Coefficient of Friction

The coefficient of friction between materials is equal to the tangent of the angle of internal friction for the material. The experimental set up consisted of frictionless pulley fitted on a frame and a topless and bottomless hollow circular sample container connected to the weighing pan through a frictionless pulley. The onion bulbs were filled in the sample holder and the weight was added to the weight pan until the sample holder just started moving, overcoming the friction on the surface. From the weights in the pan and the weight of the onion bulbs the coefficient of friction was calculated.

$\mu = Fs/Fn$

where,

μ=coefficient of static friction
Fs = force of sliding friction
Fn = normal force

Mechanical Properties of Multiplier Onion

Textural properties are important for vegetables. In vegetables, the texture is usually defined by hardness and firmness. Food texture analyser (Make: Stable Microsystems, England and model: TA XT2i) with Texture Expert Exceed 2.46 version software was used for the measuring crushing strength and penetration load or puncture test. The P/2 needle (2.0 mm diameter) probe was used to measure the puncture resistance of the onion bulb. Crushing implies the partial or complete destruction of products. Individual onion bulb was set upon a heavy duty platform. The p/75 (75 mm dia. aluminium platen) probe was brought in contact with the onion and compression force was applied. Three replications were done. The maximum force required for penetrating of the onion bulb to a depth of 5 mm was selected from the force deformation curve and recorded as penetrating and crushing load.

Results & Discussion

The results of various engineering properties for both peeled and unpeeled multiplier onion are discussed in this chapter.

Table 1: Physical properties of unpeeled and peeled multiplier onion

Physical property	Min.value	Max.value	Mean	SD
		unpeeled		
Geometrical mean diameter ,(mm)	19.47	28.68	19.84	3.47
Sphericity	0.76	1.00	0.92	0.13
Aspect ratio,(%)	47.78	74.13	63.42	8.4
Bulk density,kg/m^3	552.62	716.19	636.62	51.99
True density, kg/m^3	1070.8	2086.6	1526.82	43.08
		peeled		
Geometrical mean diameter ,(mm)	17.78	23.53	20.52	1.65
Sphericity	0.77	1.00	0.94	0.10
Aspect ratio,(%)	61.0	74.1	81.46	16.23
Bulk density, kg/m^3	530.51	738.30	627.03	69.96
True density, kg/m^3	1015.05	1170.51	1108.74	51.78

Physical Properties of Unpeeled and Peeled Multiplier Onions

The physical properties of unpeeled and peeled multiplier onion have been measured and recorded (table 1). The Geometric Mean Diameter varied from 19.47 mm to 28.68 mm for the unpeeled onions. The sphericity of unpeeled onion was 0.76 to 1.00 indicating it is almost spherical in shape. This was in confirmation of earlier work on CO-4 variety, multiplier onion[11]. Aspect ratio varied according to size of the onions. Aspect ratio was found to be 47.7 % for small size onion and 74.1% for the bigger size. The bulk density was found to be in the range 552.6 to 716.19 kg/m^3 according to size of the onions. Kaveri & Thirupathy (2015) has reported bulk density of fresh CO-4 onions as 547.48 kg/m^3. True density was determined to be 1526.82 kg/m^3. In the case of peeled multiplier onions, the geometric mean diameter was between the range 17.78 and 23.53 mm. The aspect ratio was in the range 61.0 to 74.1%. Maximum bulk density was 738.30 kg/m^3 whereas maximum true density was 1170.51 kg/m^3.

Chemical Properties of Unpeeled and Peeled Multiplier Onion

Under chemical properties, moisture content, TSS and the colour of the onions were measured and recorded (table 2). The moisture content of unpeeled onion was 76.9 % (w.b). There was no variation in TSS content for all replications which was found to be 20° Brix. The TSS of the CO-3 onions ranged from 14 to 15°Brix as reported by Banupriya *et al.,* 2015. The maximum colour values were reported as L* = 55.99, a* =17.38 and b* =16.00 for unpeeled onion.

In the case of peeled onions, the mean value of moisture content was 77.6% (w.b). The TSS content of the sample was 20 ˚ Brix. The maximum colour values of peeled onion were L* = 50.78, a* = 16.14 and b* =3.05 respectively.

Table 2: Chemical properties of unpeeled and peeled multiplier onion

Chemical Property	Min.value	Max.value	Mean	SD
		unpeeled		
Moisture content,%	70.0	76.9	74.73	3.14
TSS, Brix	20	20	20	-
Colour				
L*	46.97	55.99	50.30	3.16
a*	10.84	17.38	14.13	2.43
b*	10.54	16.00	13.21	1.93
		peeled		
Moisture content,%	76.5	78.6	77.6	0.87
TSS, Brix	20	20	20	-
Colour				
L*	42.18	50.78	45.274	3.45
a*	11.16	16.14	13.502	1.61
b*	2.64	3.05	2.84	1.67

L*= lightness
a*= green to red
b*= blue to yellow

Table 3: Frictional properties of unpeeled and peeled multiplier onion

Frictional property	Min.value	Max.value	Mean	SD
unpeeled				
Coefficient of friction				
SS	0.4	0.49	0.46	0.034
MS	0.53	0.72	0.62	0.022
Filling angle of repose, degree	26.4	37.50	31.55	3.54
Emptying angle of repose, degree	24.7	37.56	31.13	4.54
peeled				
Coefficient of friction				
SS	0.45	0.64	0.52	0.026
MS	0.42	0.71	0.65	0.084
Filling angle of repose, degree	28.8	48.36	39.35	7.34
Emptying angle of repose, degree	8.74	24.77	16.95	5.17

Frictional Properties of Unpeeled and Peeled Multiplier Onions

Frictional properties *viz.,* coefficient of friction and angle of repose for peeled and unpeeled onion are presented in table 3. The coefficient of friction was found for stainless steel and mild steel surfaces for unpeeled multiplier onion. The mean coefficient of friction for stainless steel surface was found to be

0.46 and for mild steel surface it was 0.62. The coefficient of friction was more in the case of MS due to its rough surface. The coefficient of friction for SS surface was less than the MS surface implying less resistance to flow. The filling angle of repose and emptying angle of repose were found to be on par based on the mean value.

For peeled onions, the mean coefficient of friction was 0.52 and 0.65 respectively for SS and MS surfaces. The filling angle of repose was in the range of 28.8˚ to 48.36˚ whereas emptying angle of repose was between 8.74˚ to 24.77˚.

Table 4: Mechanical properties of unpeeled and peeled multiplier onion

Mechanical property	Min.value	Max.value	Mean	SD
unpeeled				
Penetrating force, N	11.13	12.91	12.00	0.818
Crushing strength, N	118.55	157.85	138.35	15.86
peeled				
Penetrating force, N	7.60	9.62	8.42	0.79
Crushing strength, N	113. 55	145.47	124.93	11.09

Mechanical Properties of Unpeeled and Peeled Multiplier Onion

The firmness of multiplier onion in terms of penetrating force and crushing strength was determined with the help of texture analyser (table 4). The mean penetrating force was found to be 12 N for unpeeled onion. The crushing strength for the same was found to be 138.35 N. Bahnasawy *et al.,* 2004 reported that the crushing load was in the range of 341.4 to 980.7 N for the red onion of big onion variety.

The mean penetrating force for peeled onion was 8.42 N. This was lesser than unpeeled onion. This may be due to removal of outer peel of onion. The crushing strength of peeled onion was 124.93 N.

Conclusion

The various engineering properties were measured for unpeeled and peeled multiplier onion and the results of the study are: The geometric mean diameter was measured as 19.84 ±3.47 mm and 20.52 ± 1.65 mm respectively for unpeeled and peeled onions. The shape factors *viz.,* sphericity and aspect ratio was found to be 0.92, 0.94 and 63.42, 81.46% respectively for unpeeled and peeled multiplier onions. The bulk density and true density of unpeeled and peeled onions were 636.61, 1526.825 kg/m^3 and 627.03, 1108.74 kg/m^3 respectively. The moisture present in unpeeled and peeled onion was 77.66% and 74.73% (w.b) respectively. The TSS of small onion was found to be 20˚ Brix for both peeled and unpeeled samples. The colour values were also measured using colour flex meter for the peeled and unpeeled onions. The coefficient of friction for SS and MS surfaces were 0.46 and 0.62 respectively for unpeeled onion and 0.52 and 0.65 respectively for peeled onions. The firmness was measured in terms of penetrating force and crushing strength which were recorded to be 12.00, 138.35N respectively for unpeeled and 8.59, 124.93N respectively for peeled onions. From the above study it is concluded that, the engineering properties of multiplier onion becomes the basic data for designing and development of different processing equipment.

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Conflict of Interest

The authors do not have any conflict of interest.

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